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Semi-Annual Status Report

Influence of Constituent Properties and Geometric Form on Behavior of Woven Fabric Reinforced Composites

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RESEARCH OBJECTIVES

The objective of this research is to study the potential for woven fabric composite forms to increase the interlaminar strength and toughness properties of laminated composite systems. This objective will be accomplished through experimental and analytical studies on a "z-axis" fabric.

The experimental program will evaluate the following properties for T-300/934 [0/90] laminates and z-axis fabric plates:

- tensile strength (S_1^t and S_2^t)
- tensile modulus (E_1^t and E_2^t)
- poissons ratio (ν_{12}, ν_{21})
- compression strength (S_1^c, S_2^c)
- compression modulus (E_1^c, E_2^c)
- shear strength (S_{12}, S_{13})
- shear modulus (G_{12}, G_{13})
- critical strain energy release rate G_{Ic}
- compression after impact strength
- volume fraction

A comparison will be established between the laminate and the z-axis fabric properties.

The analytical program will use three-dimensional finite element analysis tc model the fabric mechanics governing the property behavior. Once developed the finite element model will become a tool for performing parameter studies which show the influence of constituent properties (fiber, resin) and geometric form (volume fraction of reinforcement, orientation and fiber crimp) on the mechanical properties. The trade offs in inplane properties will be assessed as a function of improvements in interlaminar properties obtained by z-axis reinforcement. The alternate goal would be optimization of both inplane and interlaminar properties for three-dimensionally woven fabrics.

Experimental Program

For this initial investigation a single fiber, resin and fabric configuration have been chosen. The fabric, ordered from Technaweave, is a "z"-axis fabric wherein the inplane fibers are uncrimped 3k T300 carbon fiber tows, and the "z"-axis fiber tows are 1k T-300. The fabric will be impregnated with 934 resin by either vaccuum infiltration or soaking in a heated resin bath. The resin impregnated fabric will then be autoclave cured to produce test panels, approximately 0.2 inches thick. This phase of the research is currently awaiting delivery of the unimpregnated fabric.

Another company, Proform Inc. has agreed to supply the principal investigators with additional z-axis material

with variations in the type of z-axis fiber, the volume fraction of z-axis fibers and the dispersion of the z-axis reinforcement. Test results on these fabrics will be used to help validate the analytical parameter studies.

The mechanical property characterization tests will be as follows:

Tension	- ASTM Standard D3039
Compression	- ASTM Standard D3410
Shear	- ASTM Standard D4255
G_{Ic}	- Double Cantelever Beam Test
Compression after Impact	- Boeing Specification BSS7260

Analysis

The analysis will be performed using a three-dimensional (3-D) finite element from the ADINA finite element program which allows for either linear or nonlinear, orthotropic material properties. A representative unit cell of the fabric composite, comprised of one or more fiber types and matrix material, will be modeled to analyze the fabric mechanics under load.

A micromechanical analysis has been performed to characterize the geometry of the fabric. Figures 1 and 2 show the essential features of the microstructure. By taking a sequence of sections a few thousandths of an inch

apart, the structure of the material shown in figure 3 was derived. This was used as the basis for formulating the finite element mesh.

Since both the geometric and material properties of this unit cell model are parameters which will be varied, a pre-processor is being developed tc generate meshes and map material properties into the finite-element model. The pre-processor will provide an efficient method for conducting the multitude of parametric studies necessary to assess the influence of fiber properties, resin properties, geometric configuration of the fabric weave pattern and volume fraction of fiber on the three principal material directions on the balance of properties. The pre-processor will even handle more complex weave patterns which have periodic fiber curvature and undulations through the material.

The FEM model of a unit cell of z-axis fabric assumes that the fibers are T-300 carbon with orthotropic material properties and the resin is 934 epoxy. Initially the assumption of perfect adhesion between fiber and matrix will be employed and if necessary this will be appropriately modified in later analyses. Pressure loadings will be used to simulate the state of stress on the unit cell and derive data for strength analysis. A prescribed deflection will be used to determine effective modulus of the material.

Given the stress results from the model, the strength of the material must be determined using a strength criterion. Two will be used, maximum stress, and a 3-D form of the Tsai-Wu criterion. For comparison purposes, each should provide valid relative information on material performance.

The finite element results will be checked by comparison of effective stiffnesses measured experimentally and calculated using the analysis of Chou and Ishikawa [1, 2]. Strength results will be verified by comparison with experimental results.

SUMMARY

The originally proposed objectives have been refined and a single fabric style, the z-axis fabric, has been chosen for the test program and initial finite element analysis. A detailed microstructural analysis of the z-axis fabric has been performed and a model of the basic repeating unit developed. A mesh generation and material property mapping pre-processor for the finite element analysis is under development and currently about 70 percent complete. Once completed, the pre-processor will allow efficient and rapid generation of results for the parametric study.

The experimental test program has been mapped out, the test fixturing developed and resin impregnation techniques evaluated. Currently progress is stalled awaiting delivery of the unimpregnated fabric.

References

1. Ishikawa, Takashi and Chou, Tsu-Wei "Elastic Behavior of Woven Hybrid Composites", Journal of Composite Materials, Vol. 16 (January 1982) page 2.

2. Ishikawa, Takashi and Chou, Tsu-Wei "Stiffness and Strength Properties of Woven Fabric Composites", Journal of Composite Materials Science, In Press.

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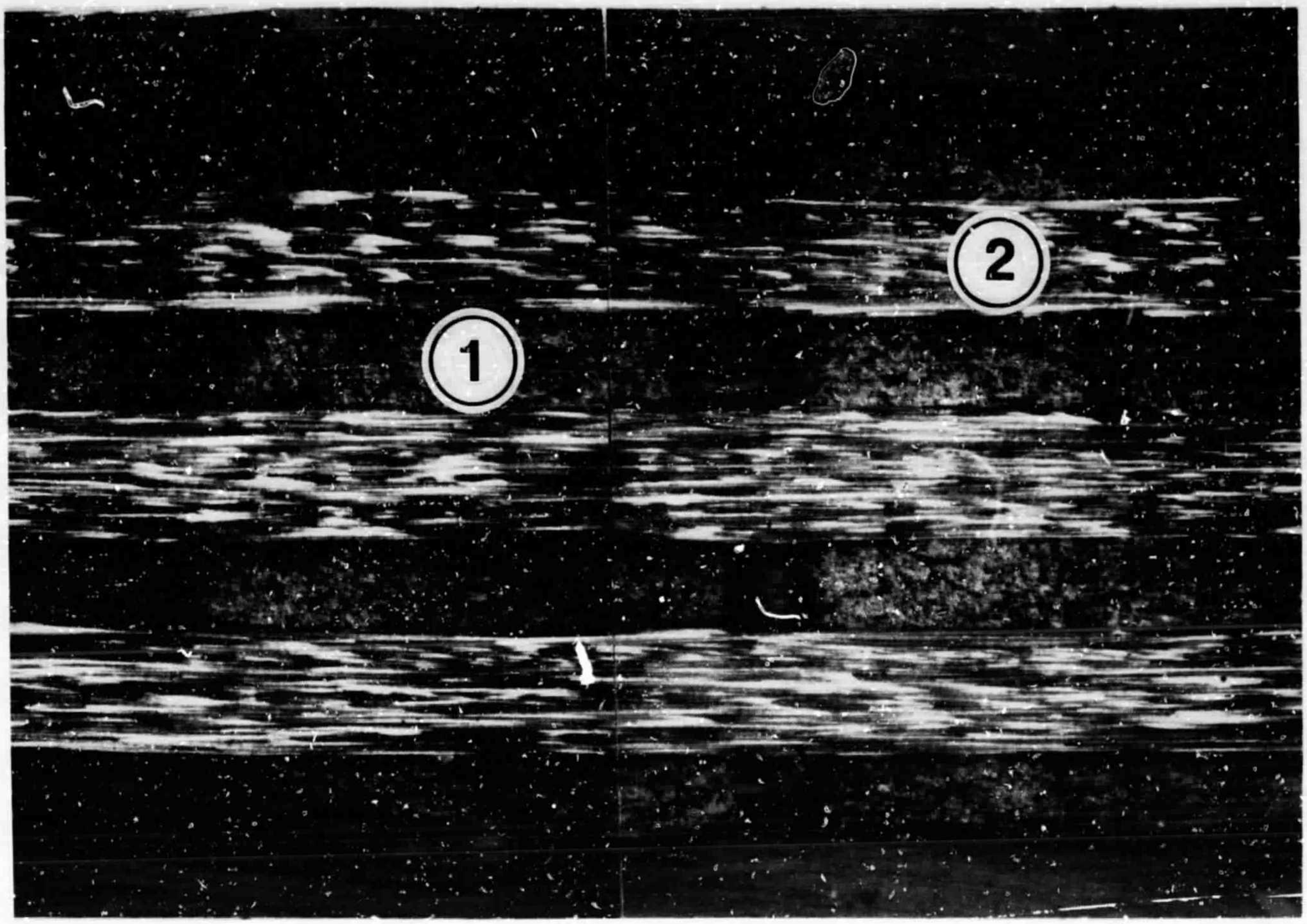

Figure 1 Warp direction cross section of z-axis fabric. (1) - fibers oriented parallel to the warp direction. (2) - fibers oriented transverse to warp direction.

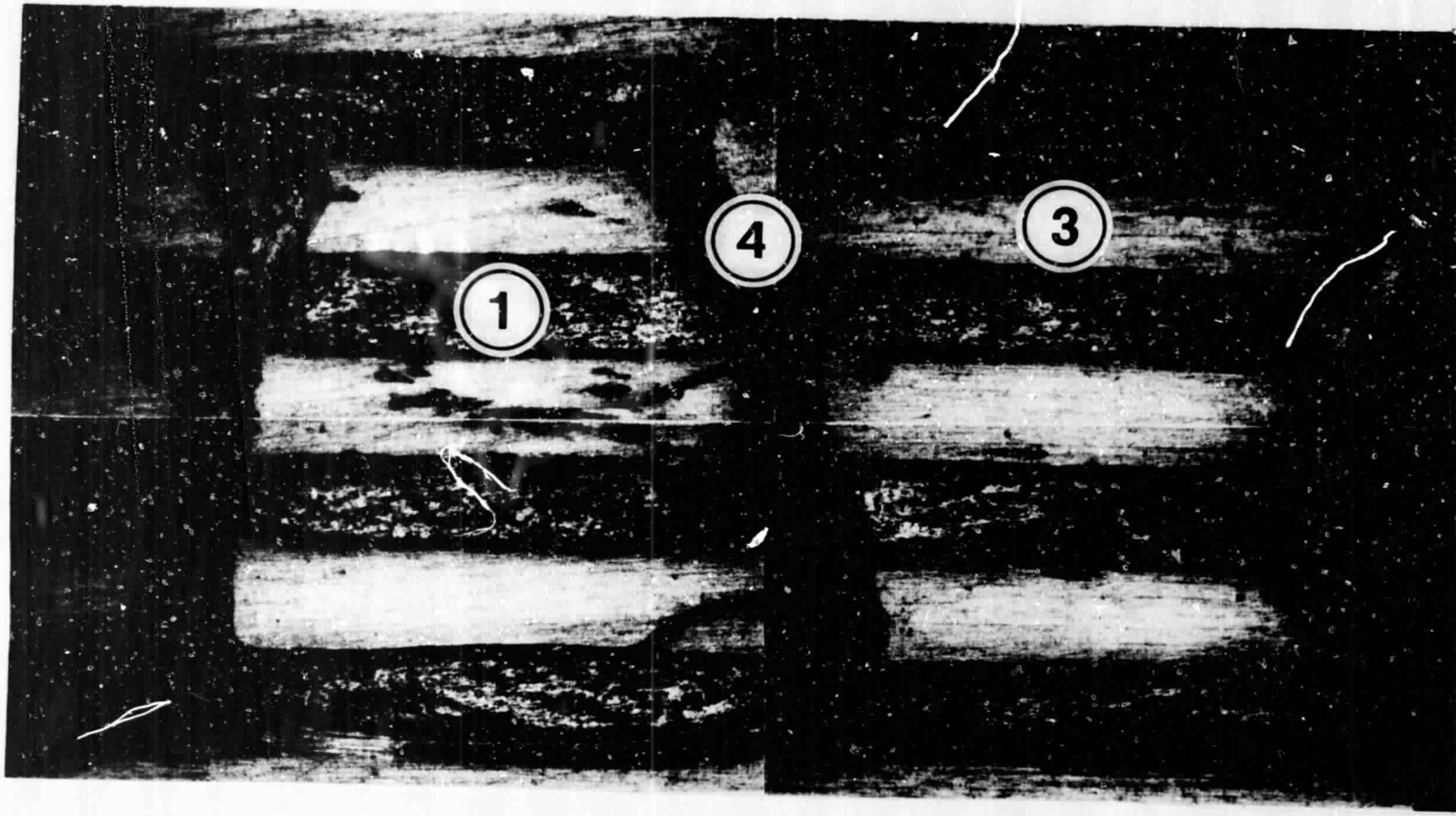

Figure 2 Cross section of z-axis fabric showing: (1) - warp direction fibers; (3) - matrix pockets between fill direction fibers; and (4) z-axis fibers.

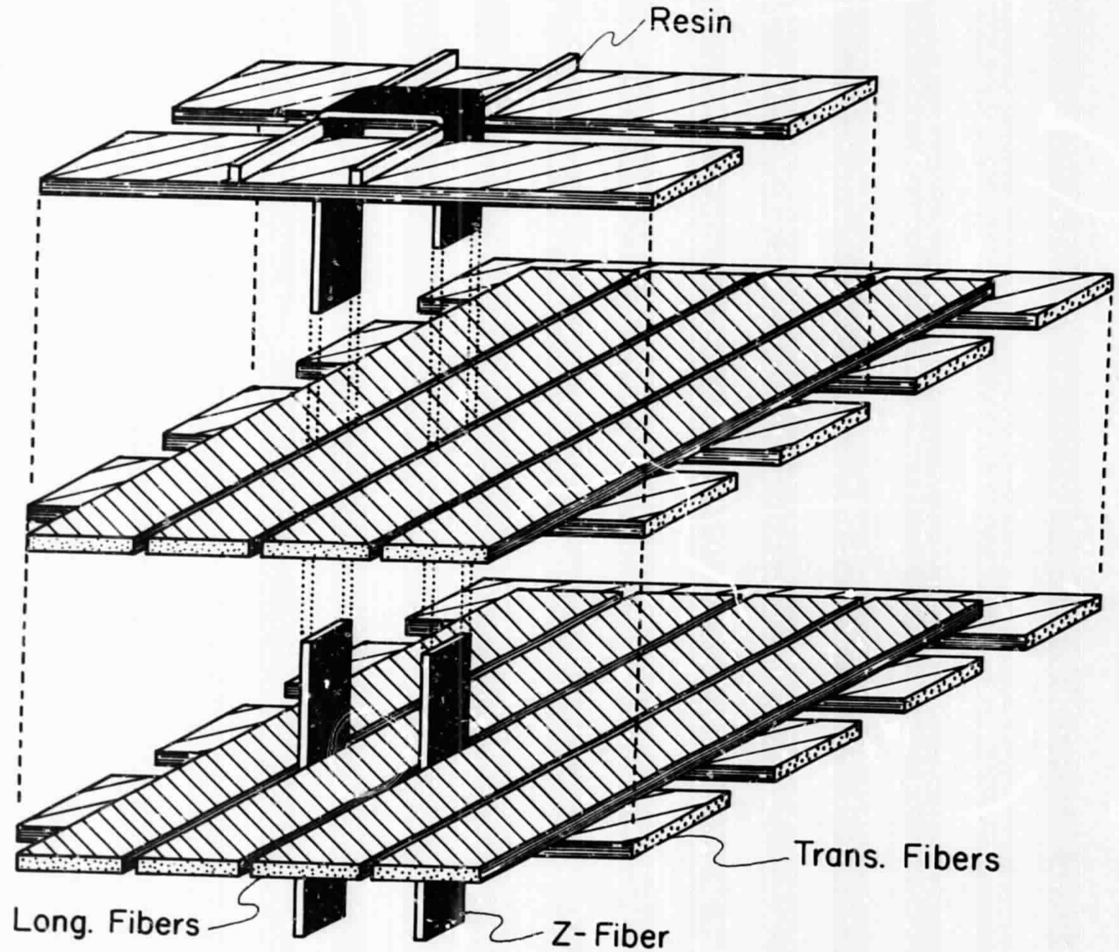

Figure 3 Simplified model of z-axis fabric.